



# Winter Manure Application and Water Quality

## Overview of the Literature



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# Overview of Briefing

- Define winter application and applicability
- Why winter application can occur
- Research findings on winter application water quality impacts and risks
- Management options
- Research needs
- Conclusions

# Purpose of White Paper

Survey of existing research on winter manure application and water quality to support an informed discussion on winter application and potential options for mitigating the effects of unavoidable winter application.



# Process

All sources of research data, management recommendations, and other information concerning winter application of animal manure:

- SERA-17 bibliography <http://www.sera17.ext.vt.edu/index.htm>.
- On-line databases: NAL, Google Scholar
- JEQ, JSWC, Trans. ASABE, others
- Grey literature
- Extension publications



Complete list of references in appendix of this presentation

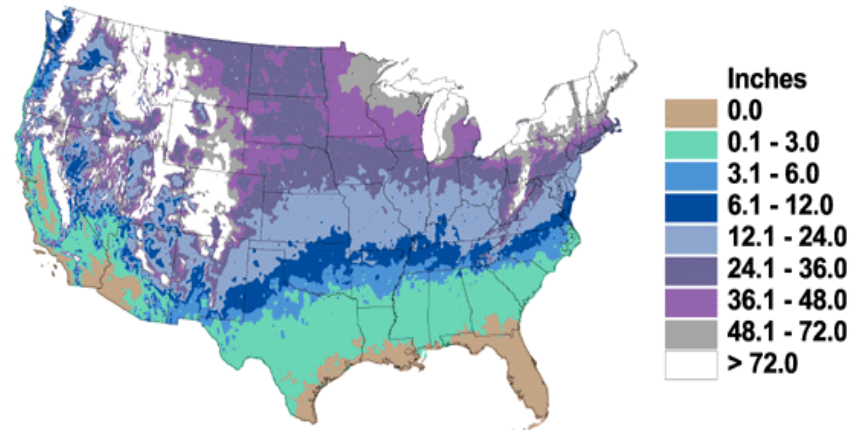


# Definitions & Applicability

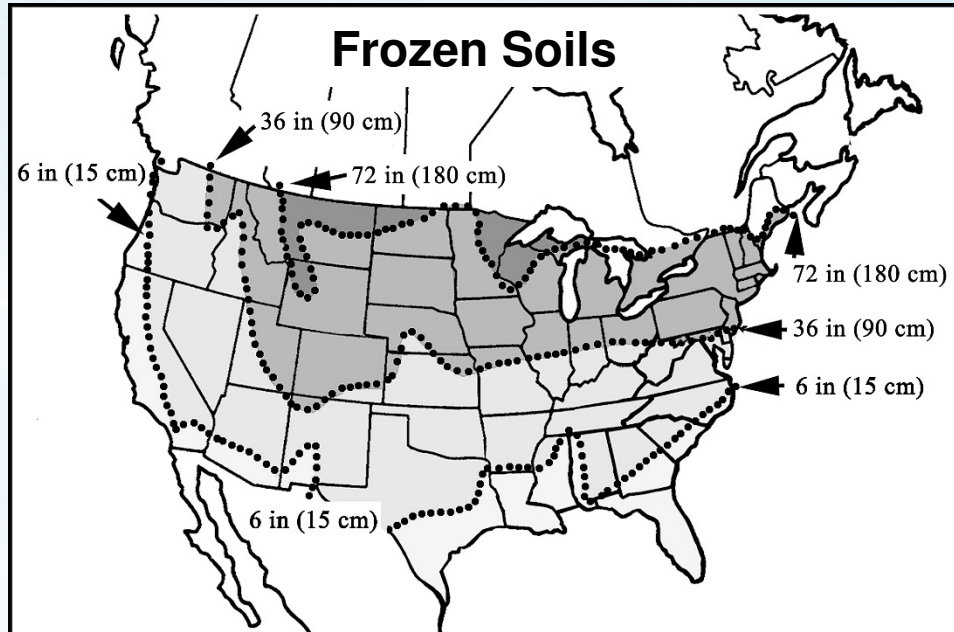
**Regions that experience frozen and/or snow-covered soils face special constraints for good manure management.**

Historical snowfall and soil frost data suggest that winter application practices warrant careful consideration in parts or all of U.S. states except Florida, Hawaii, Louisiana, and Mississippi.

## Annual Mean Total Snowfall

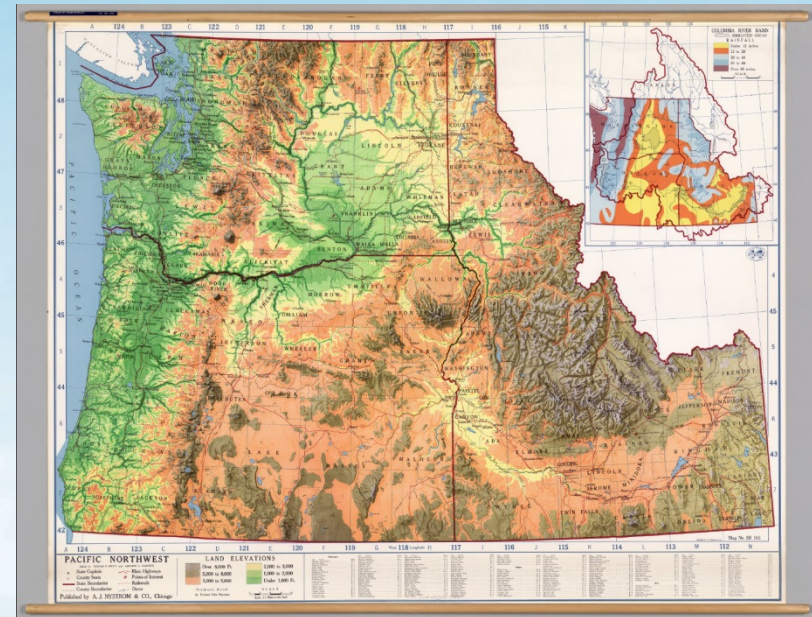


## Frozen Soils



# Definitions & Applicability

**Land application of animal manure to snow-covered, ice-covered, or frozen soils.**



Other situations outside the scope of the paper where risks also exist:

- “Warm winter” application during high precipitation periods
- Application to saturated soils at any time
- Others....



# Agronomic benefits of winter application?

The comprehensive literature review found no published research to support agronomic factors as a basis for recommending winter manure application:

- Prevention of soil compaction\*
- Reduction of N volatilization\*
- Providing crop nutrients for spring planting,
- Reduce risk of excessive manure application around a ban period

\* Both have been documented as “positives” of winter application, but other factors outweigh the benefits



# Winter Application Impacts and Risks

## Hydrologic factors

- **Frozen soils decrease infiltration and increase runoff**
  - Most (not all) frozen soils virtually impervious (Fleming and Fraser 2000)
  - 56% increase in runoff volume from frozen soils (Williams et al. 2012)
  - Catchments with frozen soils have greater water yield than unfrozen soils (Molnau and Cherry 1990)





# Winter Application Impacts and Risks

## Hydrologic factors

- **Importance of snowmelt in annual discharge**
  - WI: 50% of annual ag runoff in snowmelt (Stuntebeck et al. 2011)
  - Alberta: 90% of annual runoff (Little et al. 2007)
  - Sask.: 85% of annual runoff and 50% of groundwater recharge (Maule and Elliott (2005a))



# Winter Application Impacts and Risks

## Hydrologic factors

- **Critical characteristics**
  1. Structure of the frozen soil
  2. Depth of penetration of the frost
  3. Persistence of soil frost
  4. Areal extent of frozen soil. (Storey 1955)
- Freeze-thaw processes poorly understood (Storey 1955)
- Function of variable soil and climate characteristics, e.g., tillage, cover, moisture (Storey 1955, Willis et al. 1961)



# Winter Application Impacts and Risks

- Frozen soils and snowpack increase the risk of runoff from winter-applied manure.
- Dormant or absent crops provide no nutrient uptake
- Incorporation difficult or impossible
- Freezing does not reliably kill pathogens
- Loss of soluble nutrients and microorganisms





# Winter Application Impacts and Risks

Research data demonstrate that substantial potential exists for runoff losses of N and P and impacts to receiving waters if manure is applied to frozen soils or snow-covered ground.



- **Very high nutrient concentrations, e.g.,**
  - **TP 1.6 – 15.4 mg/L; TKN 24 – 1086 mg/L**
  - **TP increase 165 – 224%; soluble P increase 246 – 1480%; 576% increase in  $\text{NH}_3\text{-N}$  in runoff following winter application of dairy manure**
- **Mass losses of up to 27% of applied P, 22% of applied N**

Thompson et al. 1979, Melvin and Lorimor 1996, Phillips et al. 1981, Clausen 1990, 1991, Midgeley and Dunklee 1945, Hensler et al. 1970, Phillips et al. 1975, Converse et al. 1976, Klausner et al. 1976, Young and Mutchler 1976

# Winter Application Impacts and Risks

The magnitude of nutrient losses from winter-applied manure appears to be controlled by a large number of factors whose relative influence is poorly understood, including:

- Effects of soil frost on infiltration and runoff generation;
- Timing, extent, and depth of snow cover relative to manure application;
- Soil temperature;
- Snowmelt and winter rainfall;
- Timing of manure application relative to snowfall, snowmelt, and runoff;
- The form of manure applied;
- Land use/land cover, including crop, crop residue, and tillage;
- Land slope;
- Existing conservation practices; and
- Weather and climate.

# Winter Application Impacts and Risks

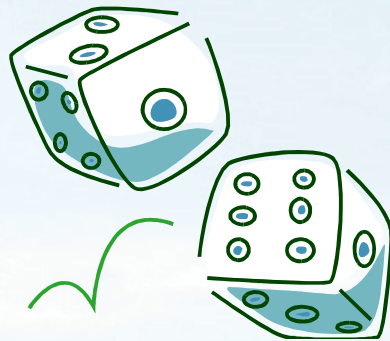
**Most of the major factors that appear to influence nutrient losses from winter-applied manure are highly variable and exceptionally difficult to predict with any certainty on a fine scale.**

→ Even if all the processes governing nutrient losses from winter-applied manure are perfectly understood, fully avoiding adverse water quality impacts – or even reasonable estimation of the risk of significant water quality impacts – from winter manure application on a site-specific basis will continue to be extremely challenging.



# Winter Application Impacts and Risks

Although the potential for major nutrient losses is not always realized, there is ample evidence in the literature that runoff losses of N and P from winter-applied manure are often significant, both in terms of agronomic losses and potential water quality impacts.



# Management standards

Some states have adopted technical standards for CAFOs, but these are highly variable

Documented in Appendix to White Paper

State	Type of Restriction					Restriction Details	Mechanism and Source
	Ban	Based on Form/Method	Exemption/ Emergency Only	Based on Location	None		
Pennsylvania				✓		<p>Applicable to NPDES-permitted CAFOs:</p> <p>Winter Spreading: The permittee shall not spread manure during the winter [December 15 through February 28; or anytime the ground is frozen at least four (4) inches; or anytime that the ground is snow covered]... except as authorized in the permittee's Nutrient Management Plan, or unless the permittee has fully complied with 25 Pa. Code § 83.372, and has obtained a plan amendment due to unforeseen circumstances... The permittee shall notify DEP in writing within 7 days prior to land application of manure during the winter period. The permittee shall certify in the notification that:</p> <ul style="list-style-type: none"> <li>a. Consistent with the approved NMP, actions have been taken to maximize the available capacity in the manure storage facility prior to the winter period to prevent pollution of ground and surface water,</li> <li>b. The storage has been properly operated and maintained, and</li> <li>c. Manure spread during the winter shall be applied in an amount and a manner consistent with the approved NMP.</li> </ul> <p>The permittee may use the Department of Environmental Protection, Winter Period Application of Manure Notification form to provide the notification.</p> <p>7. There shall be no winter application,</p> <ul style="list-style-type: none"> <li>1) Within 100 feet of an above ground agricultural drain inlet where surface flow is toward the inlet,</li> <li>2) Within 100 feet of a wetland on the National Wetland Inventory maps which is within the 100 year floodplain of an EV stream segment if surface flow is toward the wetland and</li> <li>3) Unless the fields have 25% cover or an established cover crop...</li> </ul> <p>Applicable to all operations:</p>	590 standard

# BMPs

**Most cold-climate states and provinces recommend against winter manure application and consider winter spreading to be a last resort if storage is limited or if weather impairs recommended management**





# BMPs

**Some management measures may be required to mitigate emergency or unavoidable winter application**

There is currently no body of standards and specifications supported by research data for BMPs or other management measures to specifically mitigate potential impacts of winter manure application.





# BMPs

Vegetation-based practices are largely dormant and less effective during critical mid-winter thaw and spring runoff periods when most nutrient loss occurs



# BMPs

Common sense recommendations like increased setbacks or reduced application rates may have some effect on reducing runoff losses of nutrients from winter-spread manure, but there is little documentation in the literature.

- Setbacks
- Avoid flood zones
- Slope criteria
- Proximity to water
- Residue cover
- Reduced application rate
- Incorporation/injection

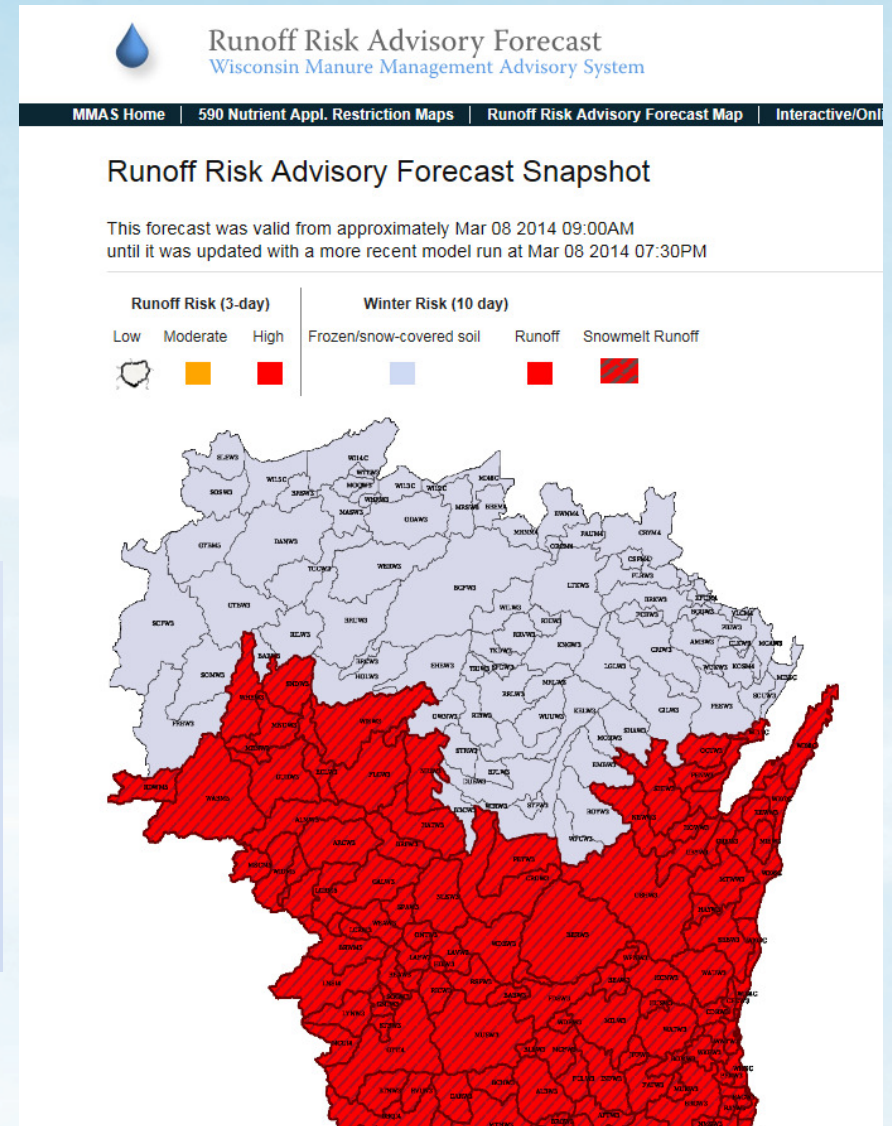


# Risk-based approaches



- Important assumptions must be communicated to users:
  - This is not meant to be the only tool for deciding when to spread
  - This approach will never produce perfect prediction
    - One farm may have runoff, the next one may not
    - Rainfall patterns, snowpack conditions, field aspect, etc.
  - Users must combine knowledge of local conditions with forecast

<http://www.manureadvisorysystem.wi.gov/>



# Risk-based approaches

New York:

- Identify the lowest risk fields for spreading as a last resort (e.g., when storage is full)
- Evaluate runoff potential along with other management needs: soil wetness, weather forecast for rainfall or snowmelt, presence of diversions or field ditches and drainage tile, rate per acre, and total amount of manure to be applied.
- When conditions for runoff are high, consider delaying the application, reducing the rate, reducing the total amount applied, and/or applying smaller amounts of manure over a period of days rather than hours
- Avoid application when:
  - Significant rainfall or snowmelt is predicted within 24-48 hours.
  - Soil is frozen, snow covered or saturated
  - Tile drains are flowing from field drainage

Czymmek et al. (2005)

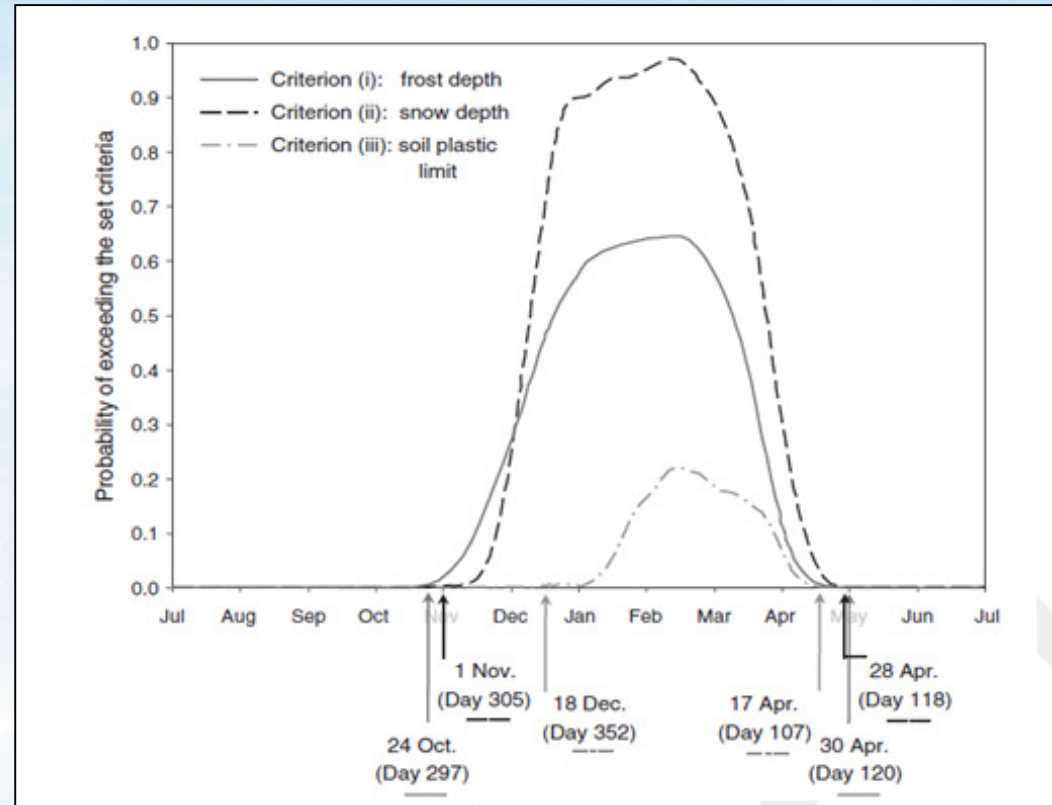
# Risk-based approaches

Ontario:

Risk assessment of conditions unsuitable for manure application:

- Soil frost depth  $> 0.05$  m
- Snow accumulation  $> 0.05$  m
- Soil volumetric water content  $\geq$  plastic limit

Range of recommended dates for spring start and fall end of manure application based on probabilities of one or more of the limiting criteria



Fallow et al. (2007)



# Many unknowns about BMPs

- ▶ Research conflicting on effectiveness of slope restrictions or requirements for vegetative cover;
- ▶ Insufficient experience with winter manure incorporation or injection to recommend a BMP
- ▶ Runoff control measures may be effective, but trade-offs with leaching are unknown;
- ▶ Effectiveness of VFS or buffers in capturing or treating runoff from winter application is uncertain because snowmelt/runoff occurs when vegetative measures are essentially dormant.
- ▶ Net effect of risk-based procedures un-tested

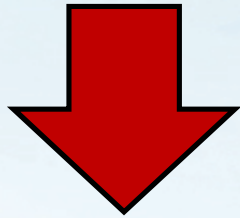
# BMP Research needs

- ▶ Identify, quantify, and prioritize individual factors influencing nutrient and pathogen losses from winter-applied manure
- ▶ Assess the real risks of major nutrient losses when limited storage and winter manure application restrictions promote high manure applications during the time immediately before or after a ban period.
- ▶ Document the effectiveness of vegetative BMPs on delivery of nutrients from winter-manured fields to surface waters during the mid-winter thaw and spring snowmelt periods.
- ▶ Evaluate the effects of BMPs currently recommended by NRCS for year-round implementation to reduce surface runoff losses of nutrients and pathogens from winter manure application and on leaching losses, in particular through subsurface drainage.
- ▶ Field test and evaluate the practicality and effectiveness of agricultural implements designed to incorporate manure directly into frozen and/or snow-covered soils.



# Weight of Evidence

- Lack of agronomic benefit,
- Documented water quality impacts, and
- Absence of effective BMPs



**Avoid winter  
manure  
application**







# QUESTIONS?

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